proper training for this kind of work, though the number is happily on the rapid increase. The 'hard parts' of the lower animals, starfish, urchins, molluscs, crustacea, insects, etc., offer ample opportunity for elementary zoölogical work, but it seems to be hardly advisable to largely recommend the dissecting of mammals by the average class, though I think the isolated parts, eye, bones of the ear, the tongue, heart, brain, etc., can be properly and very profitably used. Elaborate outfits of dissecting instruments are not here necessary, though one or two microscopes are desirable. In the secondary school there is a splendid opportunity for the cultivation of the observational powers, by comparing the external characters of animals; by observing habits; how the bird breathes; how it involuntarily grasps the branch; the adaptation of structure to use in the feet of waders, scratchers and singing birds; the structure of the scale and feathers, and claws; the pneumaticity of the bones; the preening of the feathers; the dull coloring of the female; the shapes and colors of eggs and any peculiar nesting habits. It is all wrong for a child to think that zoölogy can only be learned over a dissecting dish. The fundamental principles of biology, the theory of adaptation, protective coloring, protective and aggressive mimicry, distribution, degeneration, parasitism and development can all be illustrated to and understood by the school-child who has never held a scalpel.

The school-room already has its plants; it should also have its local collection. The children make most enthusiastic and active collectors. It is not necessary that the teacher should be qualified to give off-hand the sesquipedalian scientific name of each and every insect that is brought to the school. A far better goal is reached when the student is taught to recognize homologies, to place grasshoppers, katydids and crickets together, to have a separate apartment for butterflies and moths, and another for beetles, etc. Perhaps certain students may be interested in the molluscan fauna of the neighborhood and others may choose to collect cocoons. (I recently read in one of the ubiquitous anti-vivisection papers that the lung of the pond-snail is provided with most beautiful rows of minute horny teeth. Early observations would not only correct such aberrations, but would secure a familiarity with natural phenomena which would give that philosophical training that is often so lamentably lacking in our educated classes.) The child is delighted with the movements of aquatic animals. Aquaria should be in every school. There are hundreds of animals to be collected in any pond or stream, and how easy is it to here find themes for written exercises and models for drawing!

The zoölogy of the secondary school should not be merely an isolated subject of study. It is not attractive to some, and knowledge cannot be forced upon unwilling minds; but it can be unconsciously absorbed in solution. Zoölogy then should enter into the reading, the writing, the spelling, the arithmetic; geography is stupid without it, and the history of human progress is but distribution with the consequent 'struggle for existence' and the 'survival of the fittest.'"

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*NOTES ON THE BIOLOGY OF THE LOBSTER.**

Reproduction.—After hatching a brood in May, the female usually molts and afterwards extrudes a new batch of eggs. In

*This paper was read before the Society of Morphologists, Baltimore, December 28th.

The following observations are from part of a prolonged investigation of the habits and development of the lobster, undertaken for the U. S. Fish Commission. The detailed work, now ready to go to press, will be published in the Fish Commission's Bulletin. It will contain a full presentation and discussion of the habits and general life-history of the adult lob-

this case egg-laying follows close upon copulation. Sometimes a female is impregnated immediately after the old eggs are hatched and before the molt occurs. A second copulation is then necessary for the fertilization of the eggs. Occasionally the seminal receptacle of a lobster is found loaded with sperm a year before the eggs are due.

Laying of Eggs.—Much confusion has surrounded this subject because of the lack of continuous observation throughout the year. The facts seem to be as follows: The majority of lobsters capable of spawning lay eggs in July and August. About 20 to 25 % extrude their eggs at other times, it may be in the fall, winter or spring. During a period of seven consecutive months five traps were kept set in the harbor of Wood's Holl, Mass., December 1st, 1893, to June 30th, 1894, and visited daily. In all 168 egg-lobsters were taken; 44, or 25.6 % of the number, bore eggs which had been laid in the fall and winter.

I have tabulated 51 lobsters coming from different parts of the coast of Maine, having external eggs which had been laid out of the usual season of July and August. In one case at Matinicus Id., Maine, February 4th, the eggs had been extruded but a few hours, and the yolk was unsegmented. Another from York Id., Maine, November 15th, had eggs in a late state of segmentation of the yolk. Still another from Brimstone Id., Maine, January 27th, had eggs in the nauplius stage. At Wood's Holl, in 1889 to 1893, the recorded observations (over 300 in all) show that the greatest number of eggs are laid in the last two weeks of July, the whole period lasting from June 16th to August 31st. Data from the Maine coast (129 observations) indicate that the greatest number spawn in the first two weeks of August.

The spawning period of lobsters in the extreme north is said to last from July 20th to August 20th in Newfoundland. July and August are the months commonly assigned for the spawning in Prince Edward Island.

Number of Eggs Laid and Law of Production.—In the course of the work of lobster-hatching at the Station of the United States Fish Commission at Wood's Holl, it becomes necessary to remove the eggs from a large number of lobsters. These are carefully measured and the number deduced by simple calculation. I have tabulated the number of eggs laid in 4,645 lobsters measuring from 8 to 19 inches. In examining the column of averages one is struck by the fact that a ten-inch lobster bears twice as many eggs as one eight inches long; that a twelve-inch lobster bears twice as many as one ten inches long. It is therefore suggested that in early years of sexual vigor there is a general law of fecundity which may be thus formulated; the number of eggs produced by female lobsters at each reproductive period varies in a geometrical series; while the lengths of lobsters producing these eggs vary in an arithmetical series. If such a law prevails we would have the following:

Series of lengths in inches:

(1) : (2) : (3) : (4) : (5) : (6)
8 : 10 : 12 : 14 : 16 : 18

Series of eggs:

5,000 : 10,000 : 20,000 : 40,000 : 80,000 : 160,000.

An examination of the table shows how closely the first four terms of this series are represented in nature, and that when the 14–16-inch limit is reached there is a decline in sexual activity. Yet the largest

ster, and the habits of the larvæ and young during their period of immaturity. The history of the larva and the structure and development of the reproductive organs will be fully described, and the development of the embryo will also be reviewed. The work is illustrated by 54 full-page plates, many of which are executed in colors or reproduced from photographs, and by 40 figures in the text.

number of eggs recorded for lobsters of this size show that there is a tendency to maintain this high standard of production even at an advanced stage of sexual life.

A graphic representation of the fecundity of the lobster tells more forcibly than words or figures can do how closely it conforms to the law just enunciated. The curve which we obtain is the wing of a parabola; the curve of fecundity is parabolic up to the fourth term, where the ratio of production is distinctly lessened. The largest female lobster, carrying the largest number of eggs, was obtained at No Man's Land, June 9th, 1894. It was sixteen inches long and carried one pound of eggs, estimated to contain 97,440. It is safe to assume that the average number of eggs laid by a lobster eight inches long is not above 5,000. The large lobster just mentioned, on account of the incumbrance of its eggs, was unable to fold its 'tail,' which suggests the explanation of the rudimentary condition of the first pair of swimmeretts. If these appendages were of the average size the large number of eggs which would naturally adhere to them would make folding of the abdomen impossible, and it is by folding the 'tail' that the egg-bearing lobster so successfully protects her eggs and eludes her enemies.

Period of Incubation.—Summer eggs which are laid in July and August are ordinarily hatched in June, after a period of from ten to eleven months. Nothing is known about the hatching of fall and winter eggs. The majority of the eggs which are hatched at Wood's Holl complete their development in June.

That young are hatched at other times is certain, and we should expect this to be the case from the variations which occur in the time of ovulation. Captain Chester in 1885 hatched some eggs at Wood's Holl Station on the 8th of November and the following days, the temperature of the water varying from 54.3 to 56 degrees Fah. Some lobsters were hatched early in February in 1889 at the hatchery of the Fish Commission Station at Gloucester, Mass. The water was very cold, and it was estimated that as many as 10,000 lobsters were hatched.

Period of Sexual Maturity. Lobsters become mature when measuring from $7\frac{1}{2}$ to 12 inches in length. Very few under 9 inches long have ever laid eggs, while but few have reached the length of $10\frac{1}{2}$ inches without having done so. The majority of female lobsters $10\frac{1}{2}$ inches long are mature. Anatomical evidence shows that the period at which lobsters become mature is a variable one, extending over several years.

Frequency of Spawning. The adult lobster is not an annual spawner, but produces eggs once in two years. This is proved by the anatomical study of the reproductive organs, and confirmed by the percentage of egg-bearing lobsters which are annually captured. In a total catch of 2,657 lobsters, December 1st to June 30th, 1893 and 1894, the sexes were very nearly equally divided, and about one-fifth of the mature females caught bore external eggs. The catch off No Man's Land in 1894 amounted to 1,518 lobsters; 93.5% were females, and 63.7% carried eggs. When these results are averaged it is found that about one-half of the females carried eggs, as would be the case if they spawned every other year. Ehrenbaum is, without doubt, mistaken in supposing that the lobster does not breed oftener than once in four years (*Der Helgolander Humer, ein Gegenstand deutscher Fischerei.* Aus der Biologischen Anstalt auf Helgoland, 1894.

Gastroliths. Gastroliths are known only in two Macroura, the lobster and crayfish, and were observed in the lobster for the first time, and recorded by Geoffroy, the Younger, in 1709. Though a differentiated part of the cuticle, they are not cast off in the molt, but are retained and dissolved in the stomach. Their structure in the lobster,

consisting of hundreds of small spicules, makes the solution of them possible in a very short time.

The gastroliths have been supposed to possess great medical properties and to perform a variety of functions, the most common and accepted belief being that they play an important part in the provision of lime for the hardening of the new shell. The small quantity of lime which they contain, however, not more than one one hundred and twenty-sixth of that of the entire shell, according to an analysis recently made by Dr. Robt. Irvine, shows that this is relatively unimportant. Fragments of lime furthermore are always at hand, and are frequently eaten by the soft lobster, shortly after ecdysis, in the adolescent stages at least. It is more likely that the gastroliths are the result of excretion of lime which is absorbed from parts of the shell to render molting possible, and that their subsequent absorption in the stomach is a matter of minor importance.

Rate of Growth.—Larvæ increase in length at each molt (stages 2 to 10) from 11 to 15.84%, or on the average about 13.5% (measurements from 66 individuals). The increase in the young at each molt agrees quite closely with that seen in the adult, where the increase per cent. in ten cases was 15.3%. Allowing an increase per cent. at each molt of 15.3—probably not excessive for young reared in the ocean—and assuming the length of the first larvæ to be 7.84 mm. we can compute approximately the length of the individual at each molt.

Length at 10th molt	28.23 mm.			
" " 15th "	57.53 "			
" " 20th "	117.24 "			
" " 25th "	258.90 "	(9.5 inches.)		
" " 30th "	486.81 "	(19.1 inches.)		

According to this estimate a lobster two inches long has molted 14 times; a lobster 5 inches in length, from 20 to 21 times; an adult from 10 to 11 inches long, 25 to 26 times; and a 19-inch lobster, 30 times. These estimates do not, I believe, go very far astray. We see them practically verified up to the tenth molt.

The time interval between successive molts is the next point to consider. Here the data are very imperfect. How long is the three-inch lobster in growing to be six inches long? Probably not more than two years and possibly less. This is supported by the observations of G. Brook. We therefore conclude that a ten-inch lobster is between four and five years old, with the highest degree of probability in favor of the smaller number.

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THE NEWARK SYSTEM.

In an article in a recent number of Science* Professor C. H. Hitchcock again objects to the use of 'Newark' as a group name in geology. This article is essentially a republication of a portion of a paper by the same author, which appeared in the American Geologist in 1890† in criticism of an article of mine in the same journal,‡ in which reasons were presented for reviving the use of Newark as a name for a certain system of rocks.

I replied§ to Professor Hitchcock's objections and criticisms, and showed conclusively, as I believe, that the term referred to has precedence over all other names applied to the system in question, which do not imply correlation. In his recent article Professor Hitchcock does not so much as mention my rejoinder; but is of the opinion that the considerations presented in his earlier paper 'would have been sufficient to convince any one, looking at the subject judicially and impartially, of the inadequacy

* Vol. 1, New Series, Jan. 18, 1895, pp. 74–77.
† Vol. 5, 1890, pp. 197–202.
‡ Vol. 3, 1889, pp. 178–182.
§ Am. Geol., Vol. 7, 1891, pp. 238–241.